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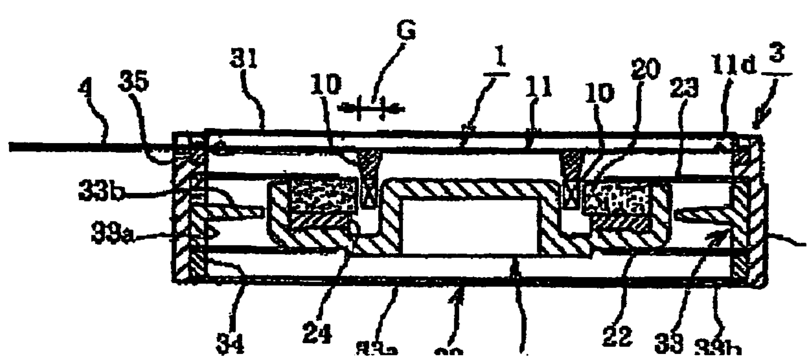
(54) ELECTROMAGNETIC ACTUATOR AND STRUCTURE FOR MOUNTING THE SAME

(57) An improved electromagnetic actuator having a coil (10) on which a current is impressed, a magnet (20) that forms a magnetic circuit across a magnetic gap (G) with a magnet yoke (21), and having a diaphragm (11) that vibrates when a high-frequency current is impressed, and a vibration plate (22) that vibrates when a low-frequency current is impressed, with these parts enclosed within a basket (3) and the coil (10) placed within the magnetic gap (G). As one invention, a radially oriented magnets, a vibration plate with a double-suspension structure, and a bottom plate of magnetic shielding material are placed in the basket to suppress the leakage of magnetic flux. As an invention to further improve the frequency characteristics by means of the mounting structure of the electromagnetic actuator, elastic packing (5, 7) is sandwiched between the basket of the electromagnetic actuator and the housing case of the portable electronic equipment, and also between the basket of the electromagnetic actuator and the mounting.

Figure 1



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FIELD OF TECHNOLOGY TO WHICH INVENTION BELONGS

[0001] This invention concerns an electromagnetic actuator and a structure for mounting it in portable electronic equipment such as a pager or portable telephone, as a means of notification of a call by means of a buzzer, audio tone or vibration when a signal is received.

BACKGROUND OF INVENTION

[0002] Pagers and portable telephones are made with built-in notification devices, which have vibrators as well as buzzers, as a means of call notification in conferences and other locations where it is inappropriate to use an audible alarm. If the vibration mode is switched on in advance, the vibrator is driven instead of an alarm being sounded when a call comes in, and the recipient is made aware of the call by means of the vibration.

[0003] In the past, this vibration has been created by a small motor, an eccentric weight attached to the shaft of the motor such that a vibration it generated when the battery-driven motor is caused to rotate.

[0004] As portable electronic equipment including pagers and portable telephones has become smaller and lighter, further miniaturization of motors has become necessary, but there are limits to the miniaturization of call notification devices with both vibrators and buzzers. Moreover, because the amount of vibration from battery drive is fixed, there is a further drawback in that there are individual differences in the strength of vibration necessary.

[0005] To resolve this problem, the applicants have developed a speaker-type electromagnetic actuator that does not use the small motor of U.S. patent no. 5,528,697.

[0006] This electromagnetic actuator is an epochal product that combines the function of selecting the vibration ring, buzzer ring or tone ring as a vibration mode into the same unit as the speaker function. It is so constituted that when a given frequency is impressed on a coil, the interaction of the magnetic field of the magnets and the current impressed on the coil generates vibration in a vibration plate in the case of a low frequency or a resonant tone in a diaphragm in the case of a high frequency. Moreover, because it is possible to control the amount of vibration and the frequency, the amount of vibration can be adjusted and set at the level desired by the individual.

[0007] As portable telephone equipment has become widely used, there has been demand for an electromagnetic actuator that can suppress the external leakage of magnetic flux and also have good frequency characteristics even though small in size. There has also been demand for high durability within the usage environment of portable electronic equipment with internal electromagnetic actuators, such that they do not break even if the user drops them. There is further demand, from the perspective of cost reduction, for reduction of the number of parts and for ease of assembly.

OVERVIEW OF INVENTION

[0008] This invention is an improved electromagnetic actuator with a small and simple structure, having a coil on which current is impressed, a magnet that forms a magnetic circuit between its poles across a magnetic gap with a magnet yoke, and having a diaphragm that vibrates when a high-frequency current is impressed, and a vibration plate that vibrates when a low-frequency current is impressed, with the coil placed within the magnetic gap and the parts enclosed within a basket. The structure for mounting the electromagnetic actuator is also improved.

[0009] One purpose of this invention is to suppress the external leakage of magnetic flux. To achieve this purpose, this invention can be constituted with a radially oriented magnets, a vibration plate with a double-suspension structure, and a bottom plate of magnetic shielding material placed in the basket.

[0010] Another purpose of this invention is to constitute the electromagnetic actuator with good frequency characteristics even when it is small. To achieve that purpose, this invention selects the material of the vibration plate and also uses the basket as a third vibrator, in addition to the diaphragm and the vibration plate.

[0011] A further purpose of this invention is to constitute an electromagnetic actuator with high impact resistance. To achieve this purpose, the invention is constituted with an elastic material that retains and supports the vibration plate within the basket.

[0012] This invention also has the purpose of cost-reduction, and is constituted with a diaphragm that holds the coil in a raised portion, and a vibration plate that holds both the magnets and the magnet yoke on its surface.

[0013] In addition, this invention has the purpose of further improving frequency characteristics and impact resistance by means of the mounting structure for the electromagnetic actuator. Thus this invention is constituted with elastic packing sandwiched between the basket of the electromagnetic actuator and the housing case of the portable electronic equipment, and also between the basket of the electromagnetic actuator and the mounting structure.

BRIEF EXPLANATION OF DRAWINGS

[0014]

Figure 1 is a cross section showing the assembly structure of the electromagnetic actuator of this invention.

Figure 2 is an exploded oblique drawing of the first vibrator, which is a structural part of the electromagnetic actuator of this invention.

Figure 3 is an exploded oblique drawing of the second vibrator, which is a structural part of the electromagnetic actuator of this invention.

Figure 4 is an exploded oblique drawing of the basket, which is a structural part of the electromagnetic actuator of this invention.

Figure 5 is an explanatory drawing showing the order of assembly of the electromagnetic actuator of this invention.

Figure 6 is an explanatory drawing showing a partial cross section of the equipment case and mounting substrate as the mounting structure of the electromagnetic actuator of this invention.

Figure 7 is an oblique drawing showing the elastic packing used in the mounting structure of the electromagnetic actuator of Figure 6.

Figure 8 is a graph showing the frequency characteristics of the mounting structure of the electromagnetic actuator without the elastic packing of Figure 7.

Figure 9 is a graph showing the frequency characteristics of the mounting structure of the electromagnetic actuator with the elastic packing of Figure 7.

DETAILED EXPLANATION

[0015] To explain this invention in detail with reference to the drawings, the electromagnetic actuator of this invention is constituted, as shown in Figure 1, with a first vibrator 1 that produces a resonant tone when a high frequency current is impressed, a second vibrator 2 that produces a vibration when a low frequency current is impressed, and a basket 3 that contains the first and second vibrators 1, 2 as the minimum necessary assembly parts.

[0016] The first vibrator 1 comprises, as shown in Figure 2, a voice coil (hereafter simply "coil")10 that is wound in a circular shape and on which either a high frequency or low frequency current can be impressed, and a thin diaphragm 11 that holds the coil 10 in place.

[0017] The diaphragm 11 is formed from a thin disk of a polymer material such as polyether imide (PEI). This diaphragm 11 has a concentric circular projection 11a that projects to a given height from the surface to hold the coil 10 in place. The surface of the diaphragm 11 also has a concentric circular lip 11d near the outer edge that divides the vibrating portion 11b from the outer rim 11c that is necessary for assembly with the basket 3. The coil 10 is fixed to the projection 11a on the surface of the diaphragm 11, and is thus held in place by the diaphragm 11.

[0018] Because of the structure of the first vibrator 1, no other support member is needed to hold the coil 10 in place, and so it is possible to reduce the number of parts and also to mount the coil 10 easily. Moreover, because the coil 10 is fixed to the projection 11a that projects from the surface of the vibrating portion 11a, it is possible for this vibrating portion 11b to maintain good frequency characteristics, unaffected by having the coil 10 mounted.

[0019] The second vibrator 2 comprises, as shown in Figure 3, a magnet 20 that forms a magnetic circuit, a magnet yoke 21 that holds the magnet 20 in place, and a thin vibrator plate 22 that holds the magnet yoke 21 in place.

[0020] The magnet 20 is shaped for a radial orientation. The magnet 20 of this radially oriented forms a ring with its north and south poles on the inner and outer peripheries to produce a magnetic circuit radiating between poles. The magnet 20 is held within the magnet yoke 21 and forms a unit with the magnet yoke 21 such that the north and south poles are positioned parallel to the first vibrator 1 and second vibrator 2. The magnet 20 is divided into four or some other number of pieces to facilitate placement in the magnet yoke 21.

[0021] The magnet yoke 21 is saucer shaped, with an outer rim 21a, and a raised pole piece 21b in the center. This pole piece 21b is a raised portio with a diameter smaller than the inner periphery of the magnet 20, so as to interpose a magnetic gap G (see Figure 1) in the inner periphery of the magnet 20.

[0022] The vibration plate 22 is punched from a sheet of springy metal, and has a springy structure with a center plate 22a that is fixed to the magnet yoke 21, an outer rim 22b that can be fixed to the basket 3, and multiple curved arms 22c that connect the center plate and the outer rim.

[0023] Because the second vibrator 2 has the radially oriented magnet 20, it is possible to suppress the leakage of magnetic flux in the direction of vibration of the diaphragm 11 and vibration plate 22 that vibrate through the attraction and repulsion by the magnetic force of the magnet 20 and the magnetic force generated by the coil 10. As with the constitution of the first vibrator 1, there is no need for a separate support member to support the magnet yoke 21, and so it is possible to reduce the number of parts and to assemble the magnet 20 and the magnet yoke 21 easily.

[0024] Now, to assure space for the coil 10 to enter to the back of the magnetic gap G in the magnet yoke 21, the yoke is assembled with a spacer 24 between it and the magnet 20.

[0025] The second vibrator 2 has, in addition to the vibration plate 22 described above, another vibration plate 23 with a center plate 23a, an outer rim 23b that can be fixed to the basket 3, and multiple curved arms 23c that connect the center plate and the outer rim. The center hole 23d of the vibration plate 23 has a diameter larger than the outer periphery of the coil 11 so that the coil 10 can be placed within the magnetic gap G.

[0026] Because the second vibrator 2 has two vibration plates 23 that form a double-suspension struc-

ture, the magnetic shielding is further enhanced and it is possible to suppress the leakage of magnetic flux even more effectively. And because it improves the vibration resistance, it is possible to maintain the initial vibration characteristics.

[0027] The vibration plates 22, 23 can be made of any stainless steel or alloy of copper and titanium that does not require an aging/hardening process alter being punched. In order to improve the hardness/Young's modulus of the spring parts of vibration plates of these materials, it is possible to increase the resonant frequency to produce a large amount of vibration. Now, multiple notches 22d, 23e are made at regular intervals in the outer rims 22b, 23b in order to fix these vibration plates 22, 23 inside the basket 3.

[0028] As shown in Figure 4, the basket 3 is formed as a low round housing that comprises a basket body 30 that accommodates the first and second vibrators 1, 2, a cover plate 31 that covers the upper side of the basket body 30, and a thin, flat bottom plate 32 that covers the bottom side of the basket body 30.

[0029] The basket body 30 is a round frame made of a polymer material such as polybutylene terephthalate (PBT). Its inner surface has steps 30a to receive the outer rim 11c of the diaphragm 11, as well as the cover plate 31. The lower side of the steps 30 projections 30b (only one is shown in Figure 4) that engage the notches 22d, 23e of the vibration plates 22, 23. The basket body 30 also has air holes 30c in its side, and on the upper edge there is a cutout 30d for the flexi substrate that makes the electrical connection with the coil 10. The cover plate 31 is disk-shaped, and has a number of sound holes 31a, 31b... This cover plate 31 can be made of a metal with magnetic properties so as to function as a magnetic shield.

[0030] The bottom plate 32 is a part of the basket 3, and is formed of a polymer--polyethylene terephthalate (PET), polyether imide (PEI) or polyimide (P1)-- so as to function as a thin vibration plate. It is best formed with a thickness not less than 50 Φm and not greater than 100 Φm.

[0031] When this bottom plate 32 is provided, it becomes a third vibrator of the electromagnetic actuator, and improves the frequency characteristics, including those of the first vibrator 1 and the second vibrator 2. Moreover, it is good to have at least one concentric lip 32a and or 32b on its surface; the lips 32a, 32b can improve efficiently the frequency characteristics of the bottom plate 32.

[0032] Within the basket 3 there is an elastic piece 33 formed of a rubber-based elastomer. This elastic piece 33 comprises a cylindrical outer wall 33a that fits against the inside of the basket body 30, and a protrusion 33b that projects inward from the outer wall 33a. The protrusion 33b of the elastic piece 33 can be continuous around the inner circumference, or it can be divided into three or four sections. In the upper edge of the elastic piece 33 there are notches 33c that fit the projections 30b of the basket body 30.

[0033] Aside from this elastic piece 33, the basket 3 has a spacer ring 34 to assure vibration spac between the vibration plate 22 of the second vibrator 2 and the bottom plate 32 of the basket 3.

[0034] Of the parts of the basket 3, as shown in Figure 1, the outer rim 22b of the vibration plate 22 is sandwiched between the elastic piece 33 and the spacer ring 34. In this way, the second vibrator 2 is supported, and the upper surface of the outer rim 23b of the vibration plate 23 is held down against the step 30b of the basket body 30.

[0035] By providing this elastic piece 33 within the basket 3, it is possible to buffer the impact force, in the event that the user drops the portable electronic equipment in which the electromagnetic actuator is mounted, by directing it from the second vibrator 2 into the elastic piece 33. Moreover, because the protrusion 33b is in contact with the outer edge of the magnet yoke 11, if the second vibrator 2 is shaken sideways on impact, the protrusion 33b acts as a stopper against the outer edge of the magnet yoke 11, thus preventing distortion of the vibration plates 23, 23. Therefore, it is possible to provide great impact resistance such that the electromagnetic actuator is not broken.

[0036] To assemble the actuator from the various parts described above, the basket body 30 is taken as the base and the diaphragm 11 with the coil 10 attached, and then the cover plate 31 are fit in to the steps 30a through the top of the basket body 30. The terminals of the coil 10 are kept long enough to allow the vibration of the diaphragm 11, and are connected electrically to the flexi substrate 4 that projects outward from the outer rim of the diaphragm 11.

[0037] From the under side of the basket body 30, on the other hand, the upper vibration plate 23 of the second vibrator 2 is inserted with the projections 30b of the basket body 30 aligned with the notches 23e. In the same way, the elastic piece 33 is inserted into the basket body 30 with the projections 30b of the basket body 30 aligned with the notches 30d, and assembled so that the outer rim 23b of the upper vibration plate 2 of the second vibrator 2 is supported. Next, the magnet yoke 21 that supports the spacer 24 and the magnet 20 is attached to the surface of the lower vibration plate 22, and the lower vibration plate 22 is inserted into the basket body 30. A spacer ring 34 that presses the outer rim 22b of the lower vibration plate 22 against the elastic piece 33 is inserted, and then the bottom plate 32 is fit into the lower opening of the basket body 30.

[0038] In the assembled actuator, the first vibrator 1 and the second vibrator 2 are facing as shown in Figure 1, and the coil 10, suspended through the central opening 23d of the upper vibration plate 23, is in position to be attracted and repulsed upward and downward within the magnetic gap G between the inner circumference of the magnet 20 and the pole piece 21b of the magnet yoke 21.

[0039] In this electromagnetic actuator, when the designated frequency is impressed on the coil 10, the electromagnetic action between the magnetic field of the magnet 20 and the current impressed on the coil 10 causes a vibration to be generated by the vibration plates 22, 23 at a low frequency, or a resonant tone to be generated by the vibration of the diaphragm at a high frequency. And because it is possible to control the amount of vibration and the frequency, the amount of vibration can be adjusted to the individual preference.

[0040] When this electromagnetic actuator is mounted in portable electronic equipment, the electromagnetic actuator is normally fixed in place within the equipment case by positioning it so as to cover the sound holes in the equipment case, with a ring of elastic packing sandwiched between the equipment case and the basket of the electromagnetic actuator.

[0041] The structure for attachment of the electromagnetic actuator of this invention is, as shown in Figure 6, to position it over the sound holes E so that a ring-shaped elastic packing 5 is sandwiched between the inside surface of the equipment case C and the basket 3 of the electromagnetic actuator A. At the same time, the elastic packing 7 is held between the basket 3 of the electromagnetic actuator A and the surface of the mounting substrate 6 that accommodates the electromagnetic actuator A within the equipment case C.

[0042] These elastic packings 5, 7 can be made of a polymer material such as urethane foam. Of these, the elastic packing 7 that is placed against the surface of the mounting substrate 6 comprises a cylindrical outer wall 7a and an elastic base 7b that extends inward from the outer wall 7a, as shown in Figure 7.

[0043] This elastic packing 7 is prepared as a part of the electromagnetic actuator A by fitting the outer wall 7a to the lower circumference of the basket body 30 as shown in Figure 6, with the elastic base 7b against the surface of the mounting substrate 6 and sported by multiple stops 6a, 6b located on the mounting substrate 6. In this way, the elastic base 7b is in place between the surface of the mounting substrate 6 and the basket 3 of the electromagnetic actuator A, and the electromagnetic actuator A is accommodated within the equipment case C.

[0044] Now, at the bottom of the electromagnetic actuator A there is, as shown in Figure 6, an opening 6c in the mounting substrate 6. And as shown in Figure 7, there can be notches 7c in the elastic base 7b that go through the outer wall 7a to provide air passages.

[0045] Regarding the effect of this structure for mounting the electromagnetic actuator, compared with the frequency shown in Figure 8 for the electromagnetic actuator mount without elastic packing, Figure 9 shows that better stability is available in frequency characteristics in the range from 800 Hz to 3 Khz, and so this structure is capable of improving frequency characteristics even though it is a small and simple structure.

[0046] The words and expressions used above in the particulars of this invention were chosen simply for the purpose of explanation, and do not limit the content of the invention in any way. In the event that limiting words or expressions have been used, that is not intended to exclude equivalent modes of this invention or parts thereof. It is clear, therefore, that it is possible to make various changes to the scope of this invention for which rights are claimed.

Claims

1. An electromagnetic actuator having a coil on which current is impressed, a magnet that forms a magnetic circuit between its poles across a magnetic gap with a magnet yoke, a diaphragm that vibrates by magnetic action when a high-frequency current is impressed and a vibration plate that vibrates by magnetic action when a low-frequency current is impressed, with the coil positioned within the magnetic gap and the parts thereof being accommodated in a basket, in which the magnet is radially oriented and positioned with its north and south poles parallel to the diaphragm and the vibration plate.

2. An electromagnetic actuator as described in claim 1 above, in which there are two vibration plates with the magnet between them, the two vibration plates providing a double-suspension structure.

3. An electromagnetic actuator as described in claim 1 or 2 above, in which the cover of the basket is used as magnetic shielding.

4. An electromagnetic actuator having a coil on which current is impressed, a magnet that forms a magnetic circuit between its poles across a magnetic gap with a magnet yoke, a diaphragm that vibrates by magnetic action when a high-frequency current is impressed and a vibration plate that vibrates by magnetic action when a low-frequency current is impressed, with the coil positioned within the magnetic gap and the parts thereof being accommodated in a basket, in which the vibration plates are made of a stainless steel or alloy of copper and titanium that does not require an aging/hardening process after being formed.

5. An electromagnetic actuator having a coil on which current is impressed, a magnet that forms a magnetic circuit between its poles across a magnetic gap with a magnet yoke, a diaphragm that vibrates by magnetic action when a high-frequency current is impressed and a vibration plate that vibrates by magnetic action when a low-frequency current is impressed, with the coil positioned within the magnetic gap and the parts thereof being accommodated in a basket, in which the basket has a thin

bottom plate that also serves as a vibration plate.

6. An electromagnetic actuator as described in claim 5 above, in which the basket has a thin bottom plate with at least one lip that is concentric with the plate.

7. An electromagnetic actuator as described in claim 5 or 6 above, in which the basket has a thin bottom plate formed of a material chosen from among polyethylene terephthalate (PET), polyethyl imide (PEI) or polyimide (PI).

8. An electromagnetic actuator having a coil on which current is impressed, a magnet that forms a magnetic circuit between its poles across a magnetic gap with a magnet yoke, a diaphragm that vibrates by magnetic action when a high-frequency current is impressed and a vibration plate that vibrates by magnetic action when a low-frequency current is impressed, with the coil positioned within the magnetic gap and the parts thereof being accommodated in a basket, in which the vibration plate is supported within the basket by an elastic piece that presses against the surface of the outer rim of the vibration plate.

9. An electromagnetic actuator as described in claim 8 above, in which the magnet yoke is supported by the vibration plate and the elastic piece has an inward protrusion that is positioned close to the outer edge of the magnet yoke.

10. An electromagnetic actuator having a coil on which current is impressed, a magnet that forms a magnetic circuit between its poles across a magnetic gap with a magnet yoke, a diaphragm that vibrates by magnetic action when a high-frequency current is impressed and a vibration plate that vibrates by magnetic action when a low-frequency current is impressed, with the coil positioned within the magnetic gap and the parts thereof being accommodated in a basket, in which the coil is supported by a concentric projection that projects from the surface of the vibrating portion, and there is a diaphragm within the basket.

11. An electromagnetic actuator having a coil on which current is impressed, a magnet that forms a magnetic circuit between its poles across a magnetic gap with a magnet yoke, a diaphragm that vibrates by magnetic action when a high-frequency current is impressed and a vibration plate that vibrates by magnetic action when a low-frequency current is impressed, with the coil positioned within the magnetic gap and the parts thereof being accommodated in a basket, in which the coil is supported by a concentric projection that projects from the diaphragm, and the coil and diaphragm are assembled in a single unit.

12. An electromagnetic actuator having a coil on which current is impressed, a magnet that forms a magnetic circuit between its poles across a magnetic gap with a magnet yoke, a diaphragm that vibrates by magnetic action when a high-frequency current is impressed and a vibration plate that vibrates by magnetic action when a low-frequency current is impressed, with the coil positioned within the magnetic gap and the parts thereof being accommodated in a basket, in which the magnet is held in a magnet yoke and the magnet yoke holding the magnet is supported by the surface of the vibration plate, and the magnet, magnet yoke and vibration plate are assembled in a single unit.

13. An electromagnetic actuator mounting structure for mounting an electromagnetic actuator inside portable electronic equipment in which elastic packing is sandwiched between the inner surface of the equipment case and the basket of the electromagnetic actuator and between the basket of the electromagnetic actuator and the electromagnetic actuator mounting substrate, so that the electromagnetic actuator is mounted inside the portable electronic equipment.

14. An electromagnetic actuator mounting structure as described in claim 13 above, in which the elastic packing is fitted to the bottom of the basket, and is sandwiched between the basket of the electromagnetic actuator and the mounting substrate.

Figure 1

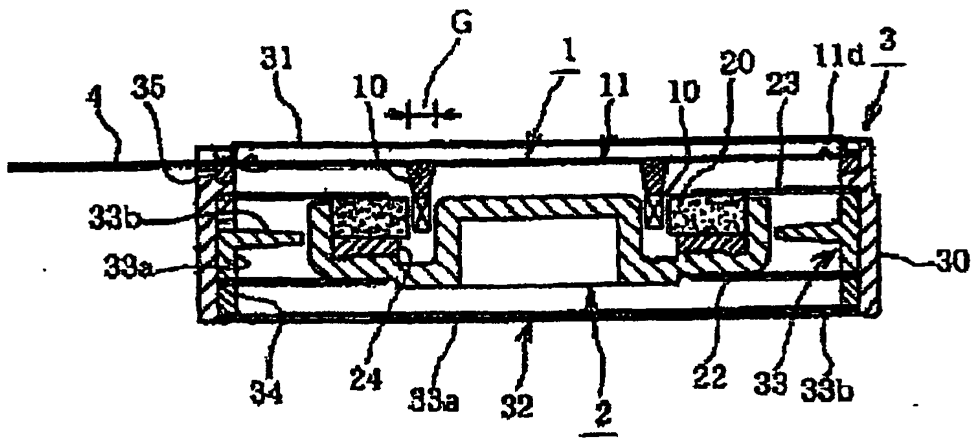

Figure 2

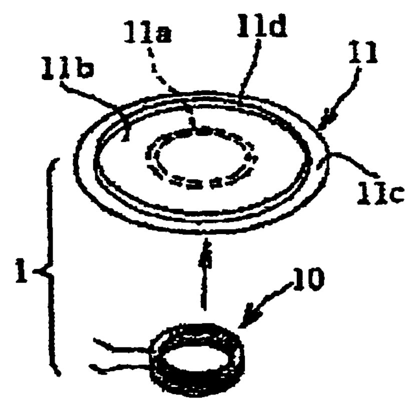

Figure 3

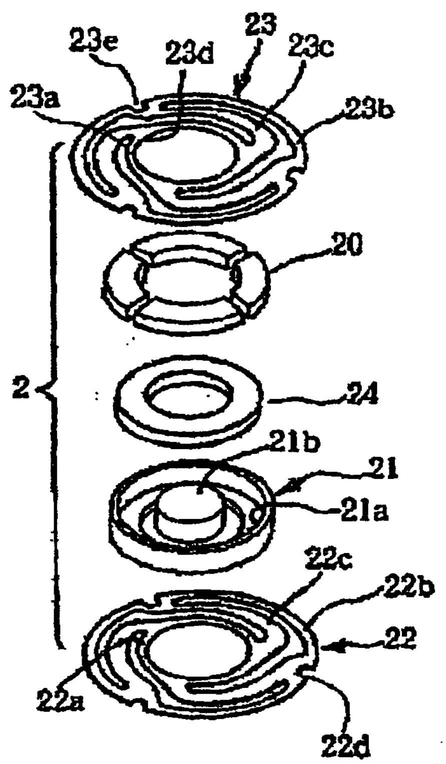

Figure 4

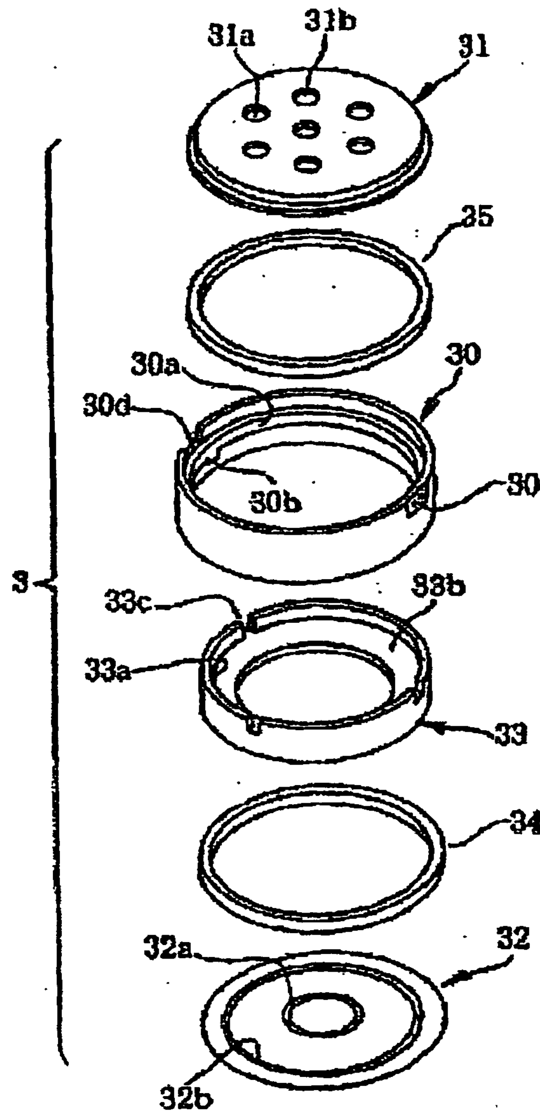

Figure 5

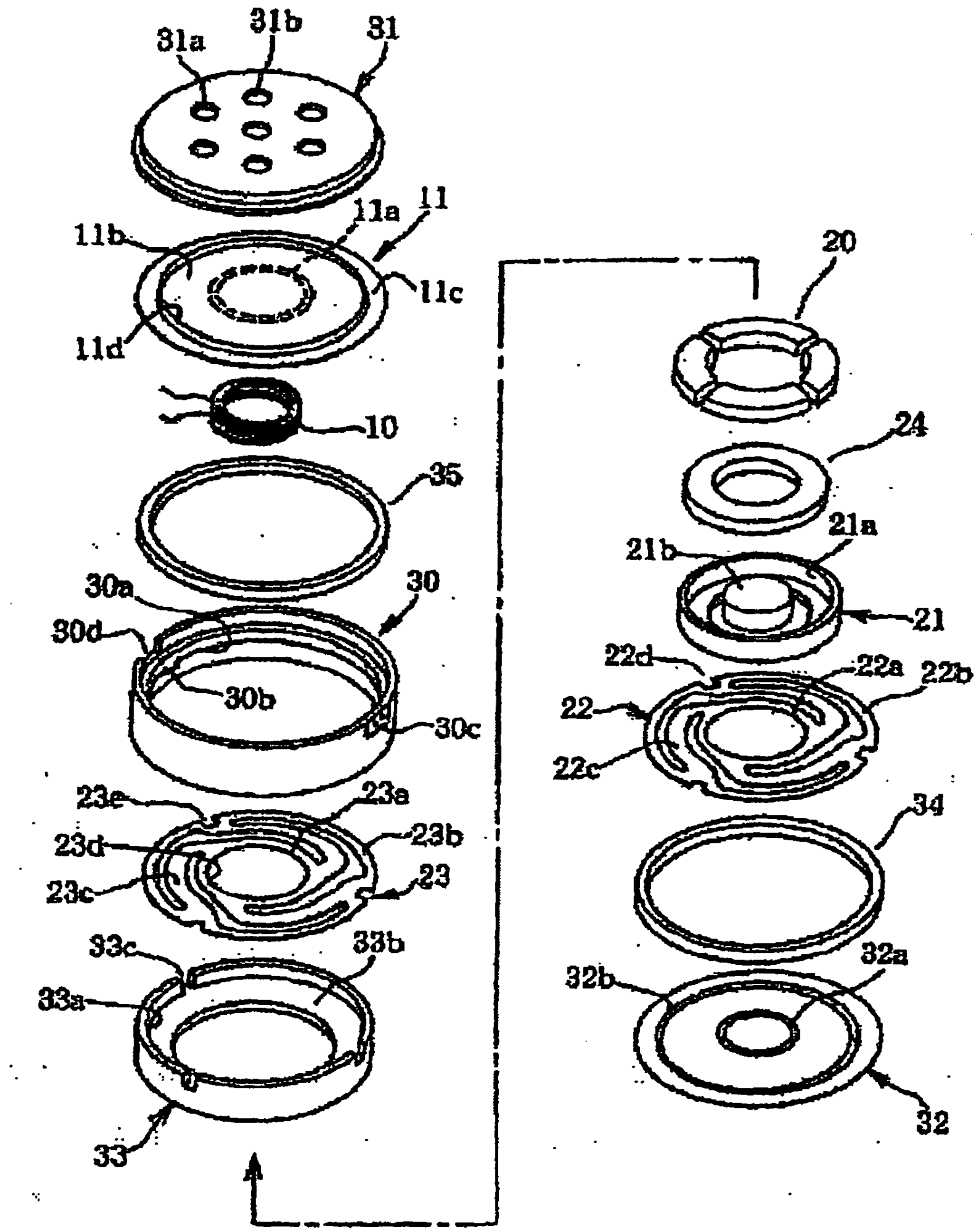
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Figure 6

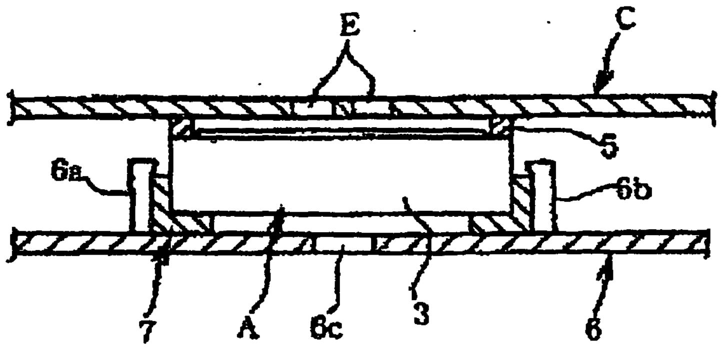
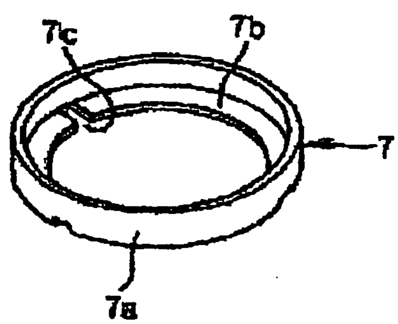


Figure 7



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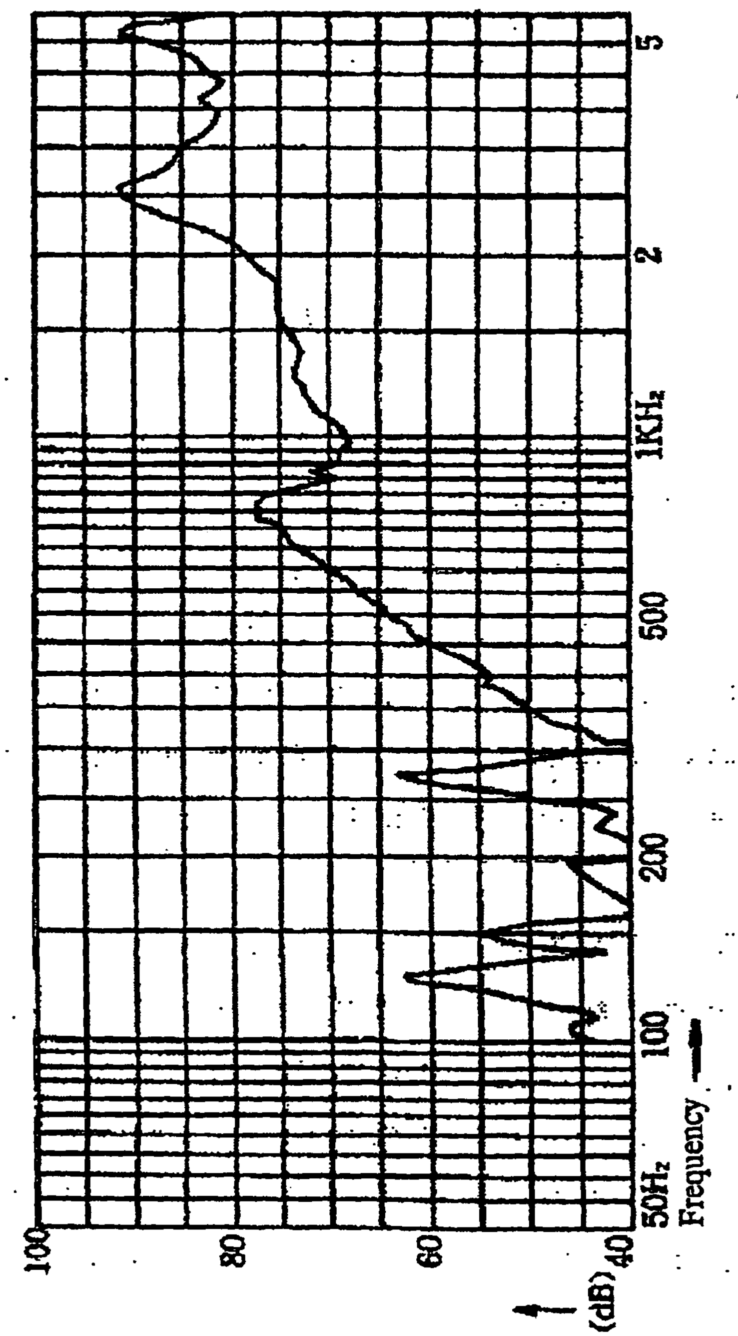


Figure 9

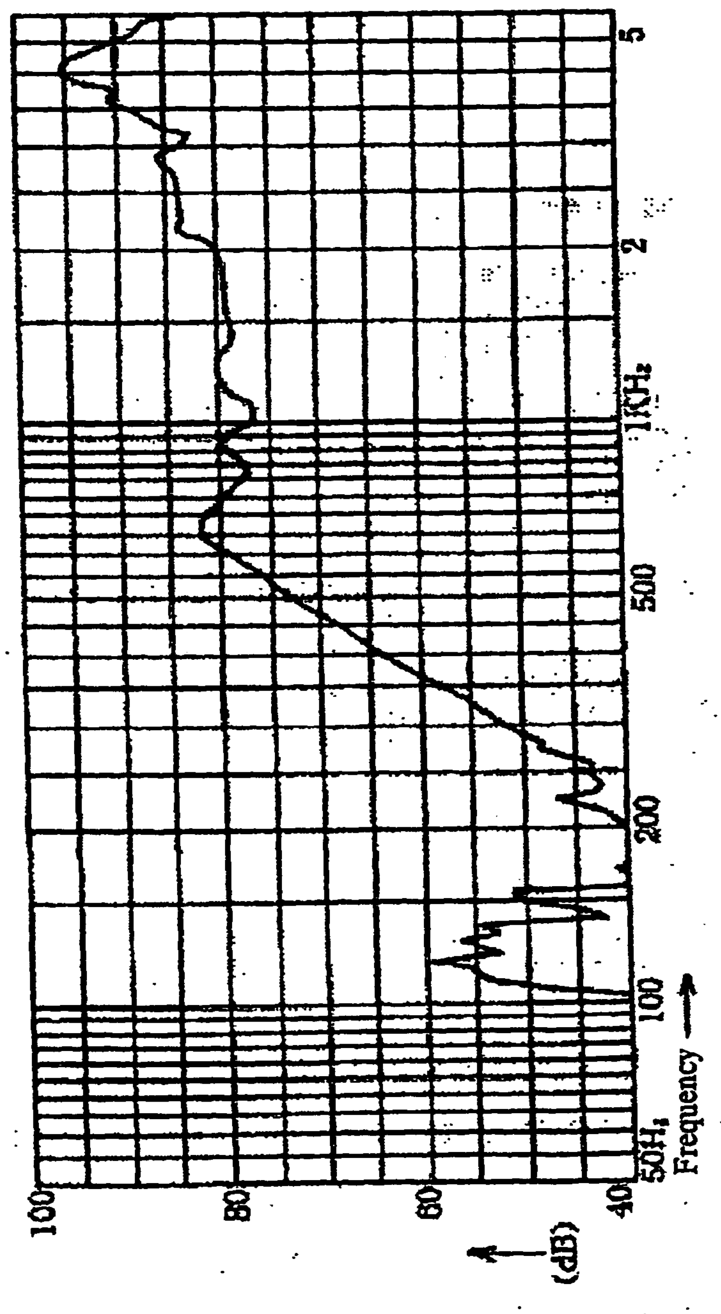


Figure 1

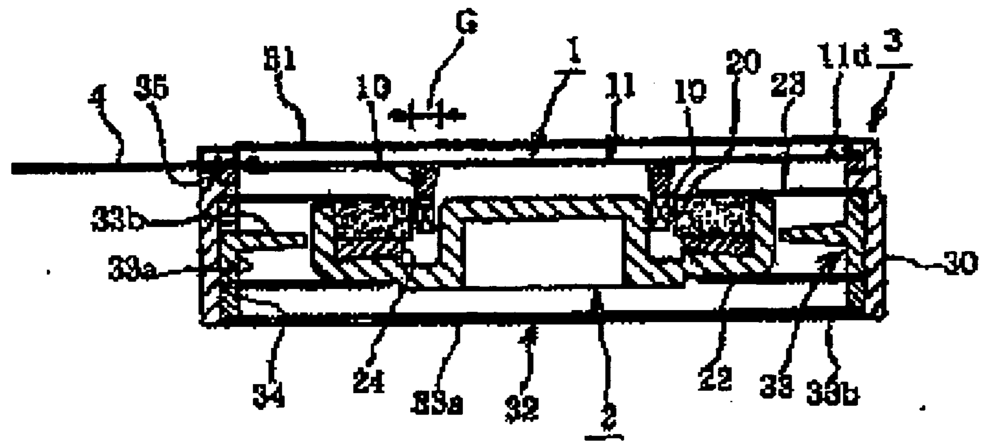
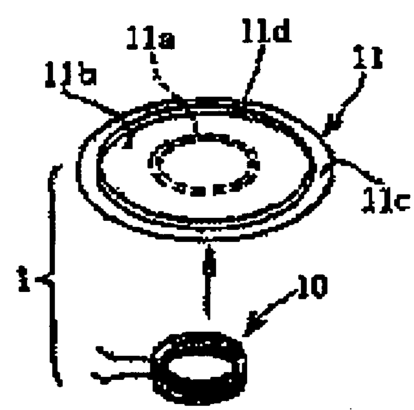


Figure 2



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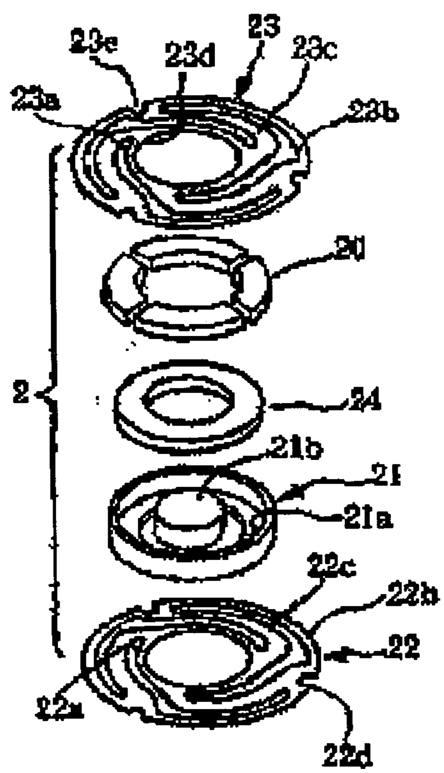

Figure 4

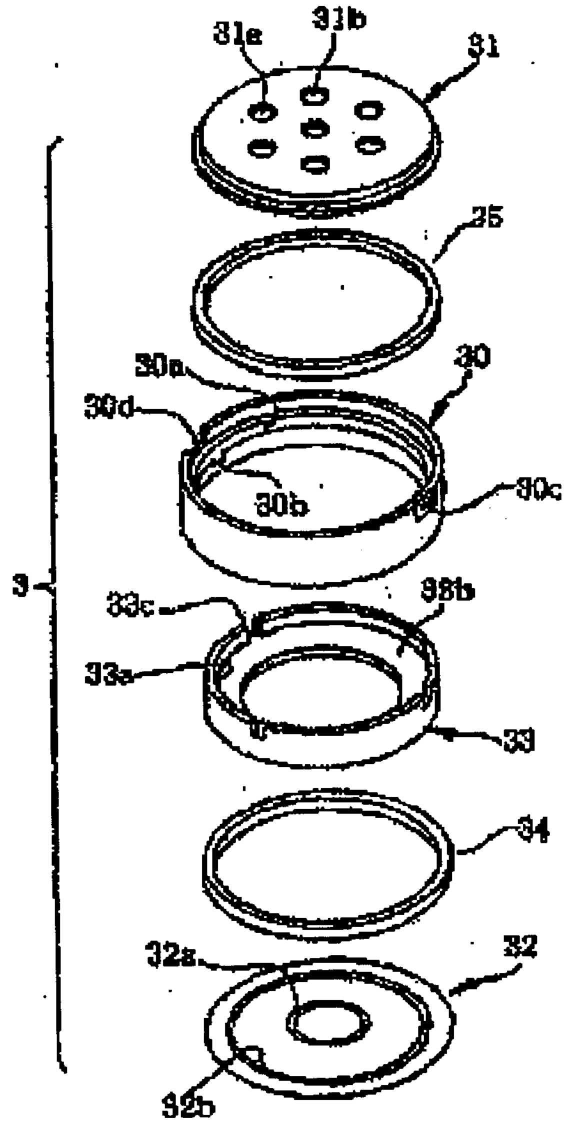

Figure 5

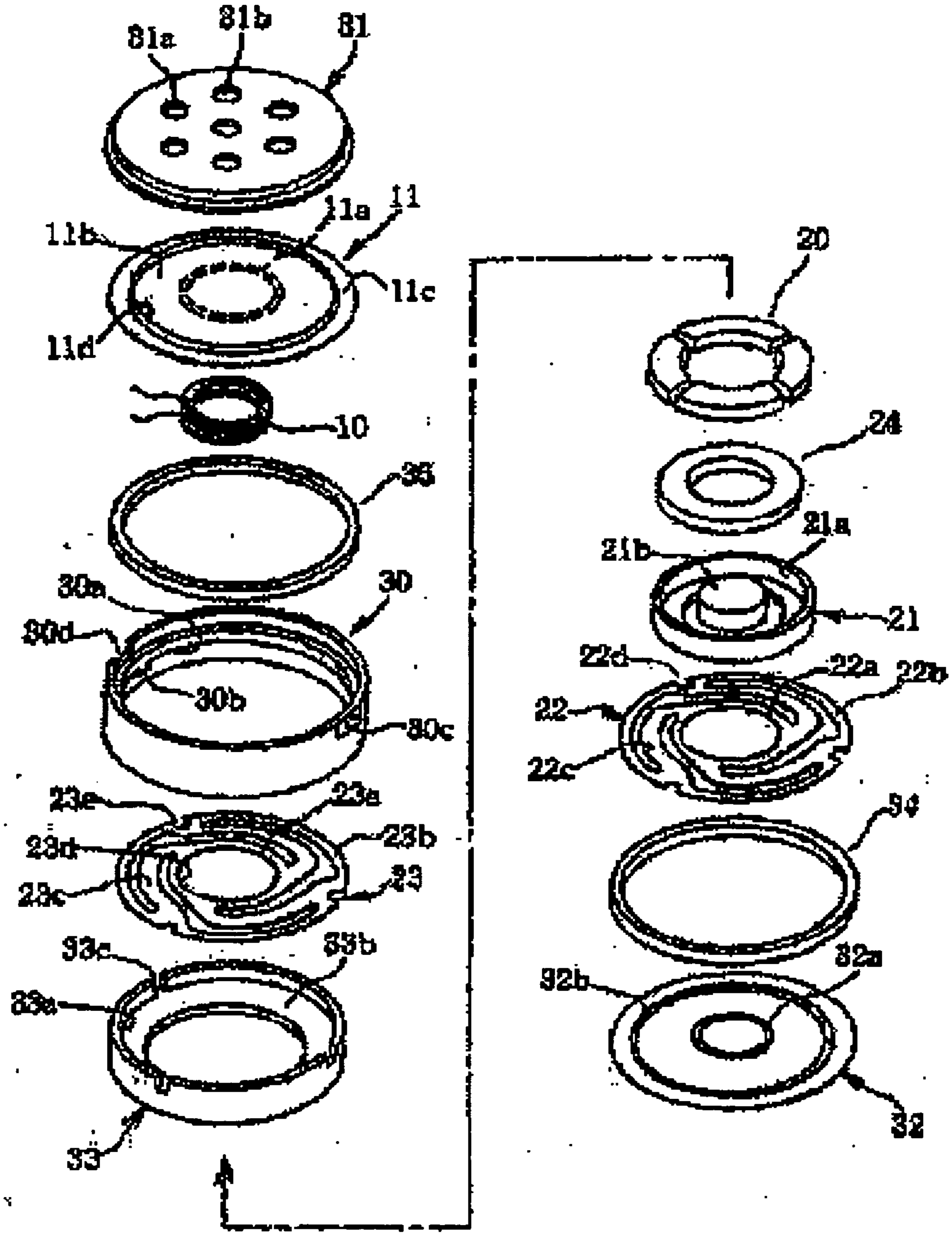
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Figure 6

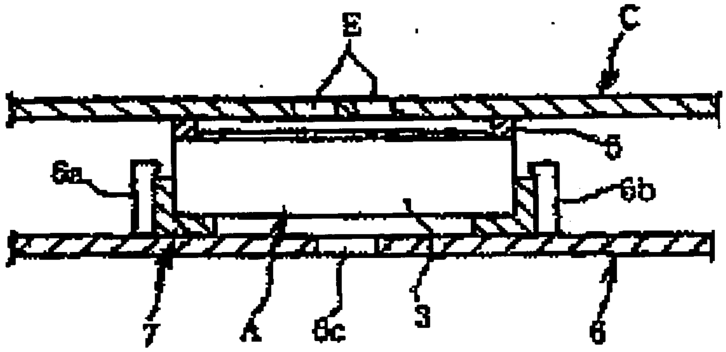


Figure 7

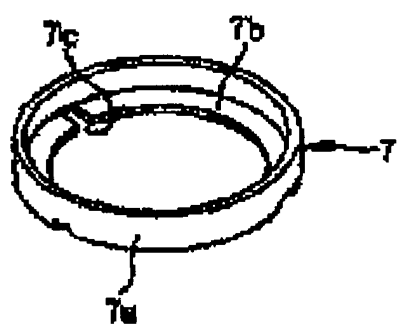


Figure 8

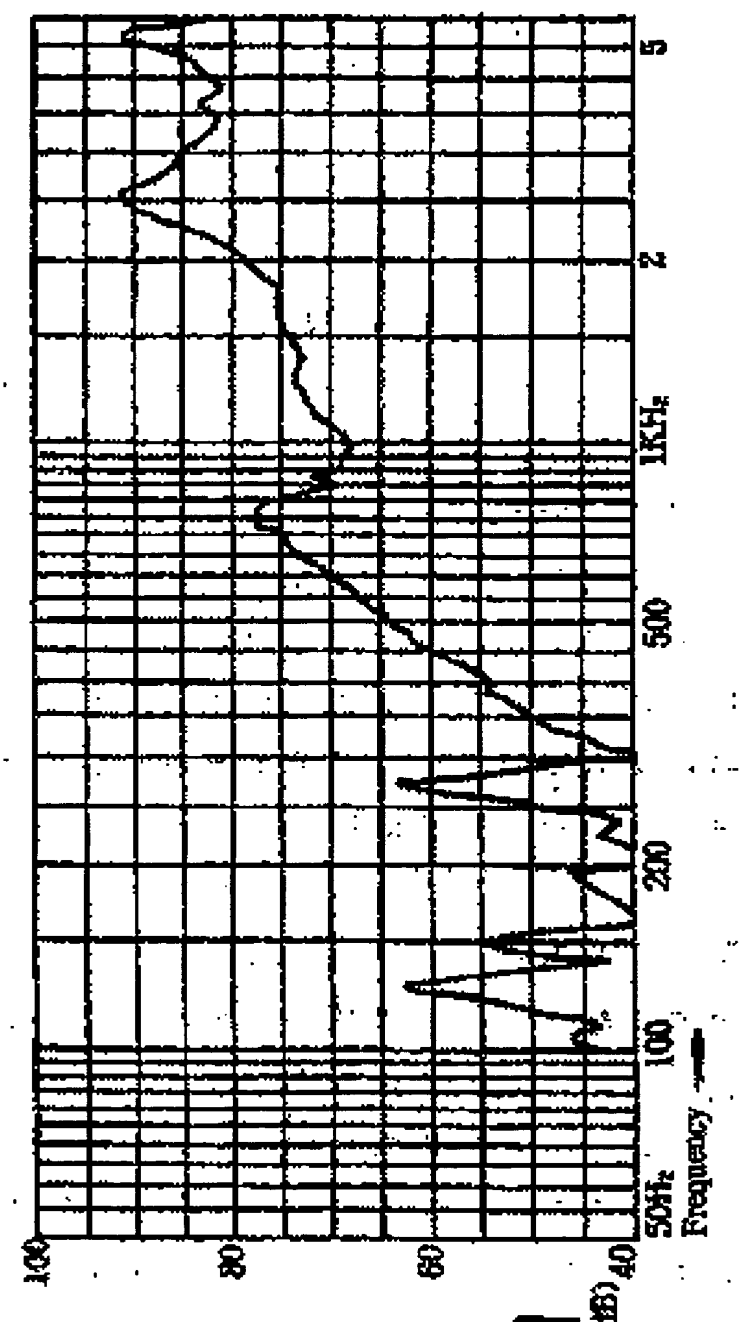
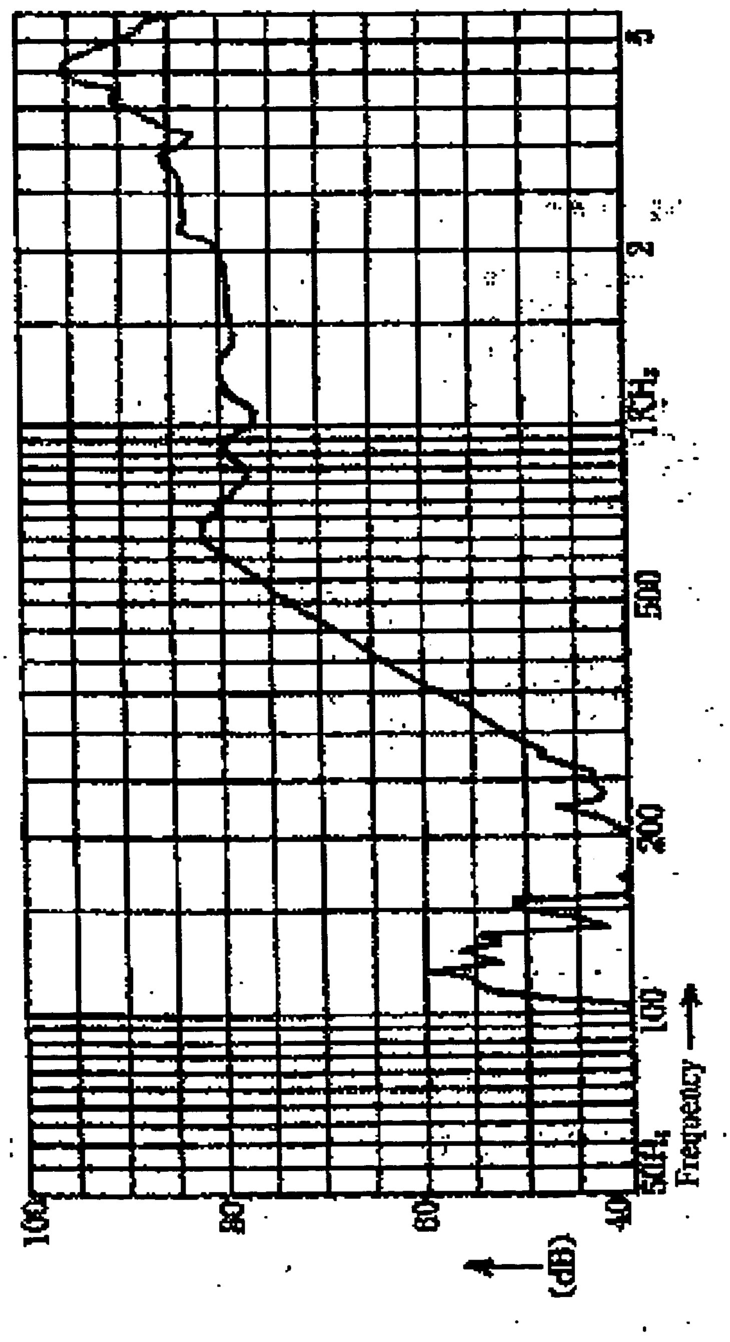


Figure 9



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP98/01673

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl^6 B06B1/00, H04R9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl^6 B06B1/00, H04R9/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1926-1998 Toroku Jitsuyo Shinan Koho 1994-1998
Kokai Jitsuyo Shinan Koho 1971-1998

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E	JP, 10-117472, A (Matsushita Electric Industrial Co., Ltd.), May 6, 1998 (06. 05. 98) (Family: none)	1
A	JP, 1-171191, U (Sony Corp.), December 4, 1989 (04. 12. 89) (Family: none)	2
A	JP, 9-275671, A (ACE Tekku Yugen Kaisha), October 21, 1997 (21. 10. 97) (Family: none)	3-14
A	JP, 9-261917, A (ACE Tekku Yugen Kaisha), October 3, 1997 (03. 10. 97) (Family: none)	3-14

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
July 10, 1998 (10. 07. 98)	July 21, 1998 (21. 07. 98)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

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